CRREL REPORT 99-4

19990611 063

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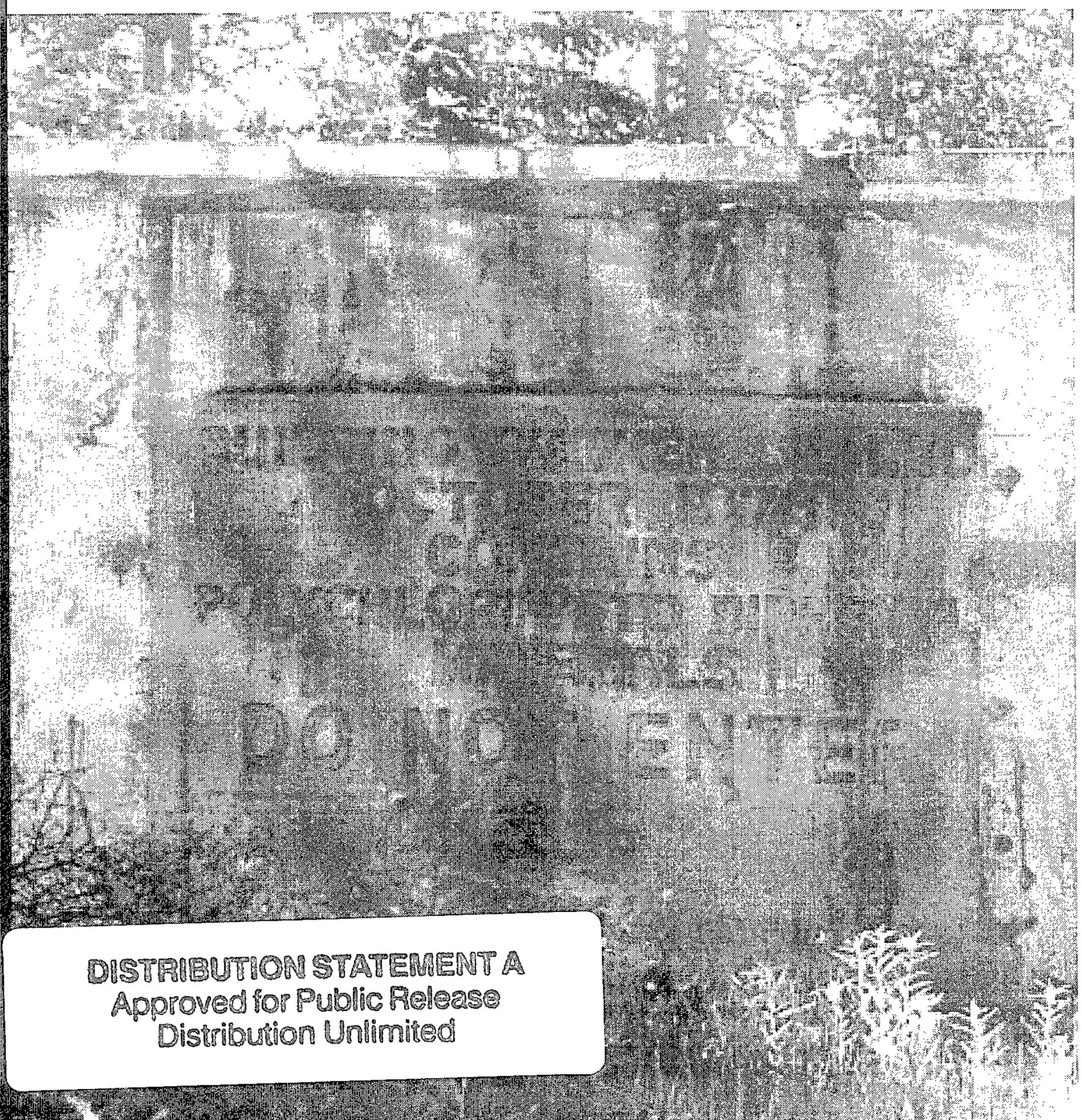
Investigation of the Roosevelt Road Transmitter Site, Fort Richardson, Alaska, Using Ground-Penetrating Radar

Lewis E. Hunter, Allan J. Delaney, and Daniel E. Lawson

March 1999



Abstract: The Roosevelt Road Transmitter Site is the location of a decommissioned bunker on Fort Richardson, near Anchorage, Alaska. The site was used from World War II to the Korean War as part of an Alaskan communications network. The bunker and support buildings were vandalized following its decommission-ing in the mid-1960s, resulting in PCB contamination of the bunker and soils around the above-ground transmitter annex. CRREL conducted a ground-penetrating radar (GPR) investigation of the site in June 1996, at the request of the Directorate of Public Works on Fort Richardson. Nine transect lines were established, each being profiled with 100- and 400-MHz antennas. Both antennas systems defined the extent of the bunker and identified the presence of buried utilidors. The 100-MHz antenna provided large-scale resolution of the bunker, limits of site excavation, and large stratigraphic horizons in the undisturbed sediments. The 400-MHz antenna provided finer resolution that allowed identification of steel reinforcement in the bunker ceiling, utilidor walls and floor, and the walls of the inner and outer bunker. High amplitude resonance and hyperbolas in the record characterize the response from the Transmitter Annex foundation, buried pipes, and utilities. The GPR survey shows its utility for detecting the extent of abandoned underground structures and identifying the extent of original ground excavations.

Cover: Concrete slab sealing the entrance to PCB-contaminated bunker at the Roosevelt Road Transmitter Site, Fort Richardson, Alaska.

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Prepared for
U.S. ARMY ALASKA

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PREFACE

This report was prepared by Dr. Lewis E. Hunter, Research Physical Scientist, Geochemical Sciences Division, Allan J. Delaney, Physical Science Technician, Snow and Ice Division, and Dr. Daniel E. Lawson, Research Physical Scientist, Geochemical Sciences Division, U.S. Army Cold Regions Research and Engineering Laboratory.

Funding for this work was provided by the Directorate of Public Works, U.S. Army Alaska, Fort Richardson. The author thanks Dr. Jeffrey Strausser for assistance in the field and initial data analysis; technical review was provided by Dr. Steven A. Arcone and Dr. Norbert E. Yankielun, both of CRREL. The authors express their thanks to Crystal Fosbrook and Kevin Gardner, Department of Public Works, Fort Richardson, Alaska.

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Investigation of the Roosevelt Road Transmitter Site, Fort Richardson, Alaska, Using Ground-Penetrating Radar

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INTRODUCTION

The Roosevelt Road Transmitter Site was the location of a high-frequency transmitter facility constructed during the early 1940s (Fig. 1 and 2). Its purpose was to provide uninterrupted communications as part of the Alaska Communications System in the event of an attack on Anchorage or Fort Richardson. The facility was self-supporting, with sanitation, a water supply, and living quarters. There were several above-ground support facilities, consisting of multiple satellite buildings for electrical and communications equipment, storage, and housing, and a mess hall (Ecology and Environment 1996). A communications bunker, tunnels, multiple buried cables, water lines, utilidor ducts, and a septic system were below ground. The exact dates of occupation of this site are unknown, but it was used roughly from World War II to the end of the Korean War. The transmitter site was decommissioned in the mid-1960s, but subsequent use included intermittent training exercises in the bunker and around the transmitter annex.

The site became contaminated when the bunker and annex were vandalized in the 1970s. In the process of stealing copper wiring from floor trenches in the bunker and transmitter buildings, vandals toppled transformers (Fig. 2b) to uncover the wiring, which spilled dielectric oils contaminated with polychlorinated biphenols (PCBs) (Ecology and Environment 1996). In 1978, the above-ground structures were removed, leaving behind a number of concrete pads (Fig. 2a). The PCB-contaminated oils that had seeped into the foundation of the transmitter annex were cleaned up by triple washing the concrete with diesel fuel. However, some of this fuel spilled off of the pad, allowing PCB-contaminated diesel solvent to leach into the ground. Soil analyses in 1988 by the Corps of Engineers found PCB concentrations of up to 76,900 ppm near the east entrance of the bunker,

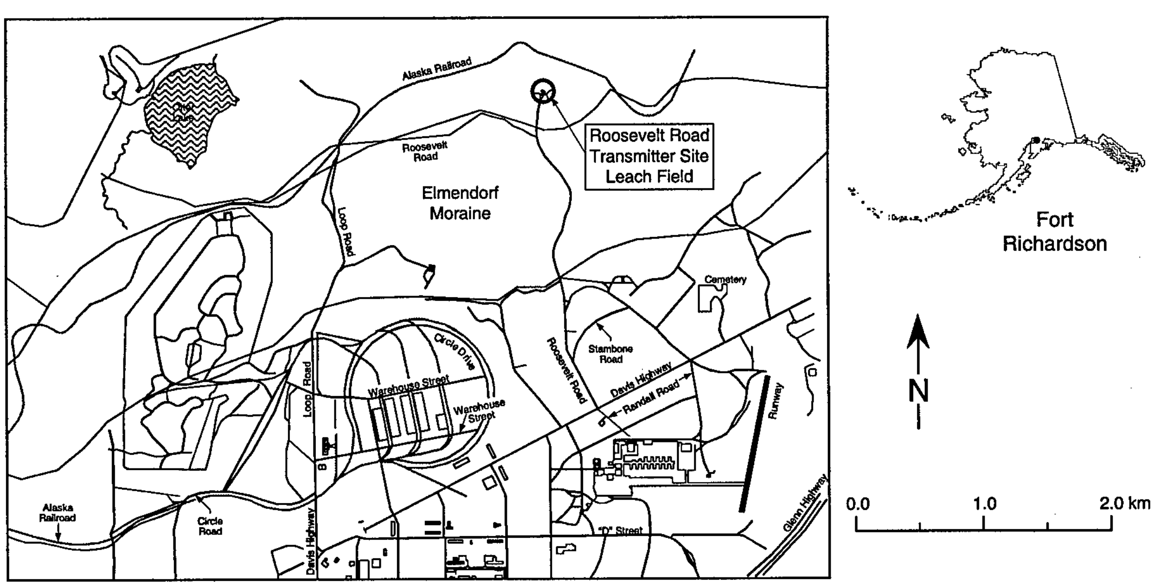
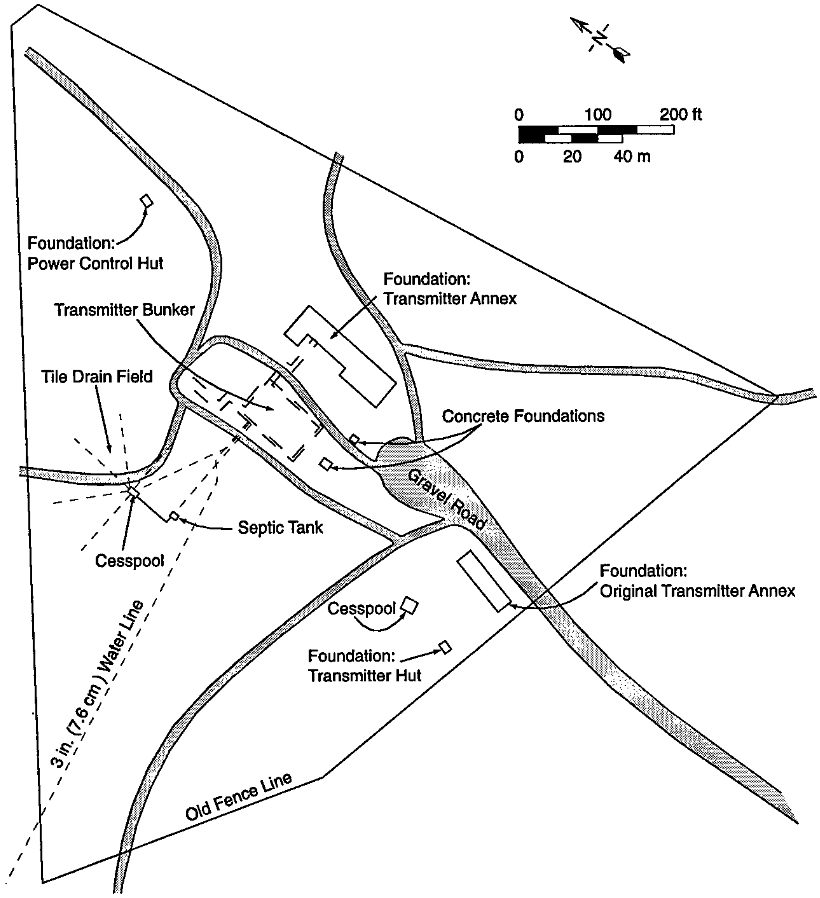
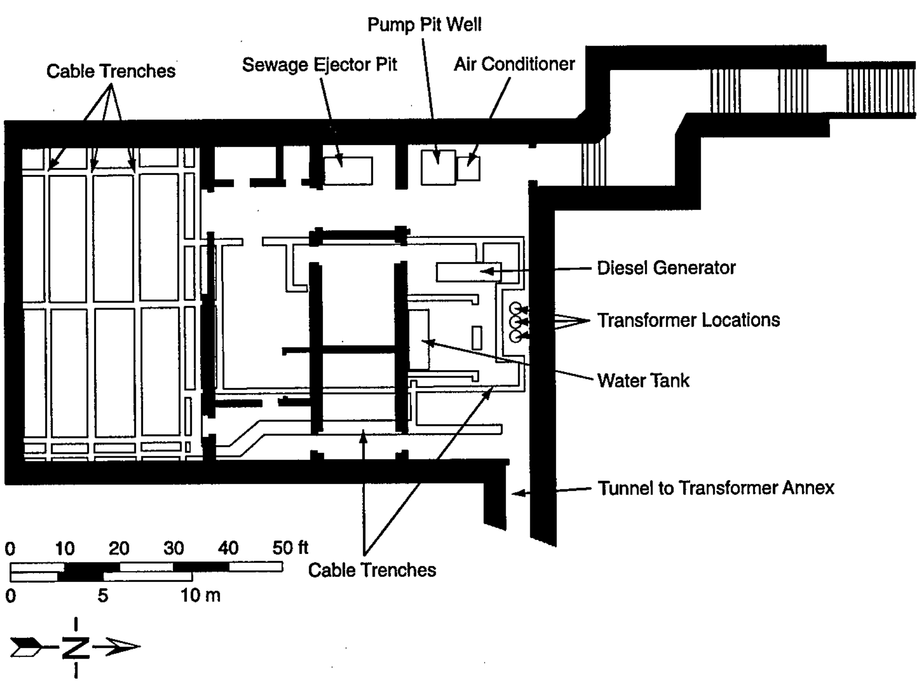


Figure 1. Location of Roosevelt Road Transmitter Site on Fort Richardson, Alaska.



a. Transmitter site compound and associated structures.



b. Inner bunker and selected details of the structure.

Figure 2. Roosevelt Road Transmitter Site.

adjacent to the transmitter annex (Ecology and Environment 1990, 1996). Subsequently, the Corps of Engineers contracted for the removal of 150 tons of PCB-contaminated soil in 1988 and another 600 tons in 1992. PCB-contaminated oils in the bunker complex were not removed, but the damaged transformers were taken away and the bunker was reportedly sealed.

In June of 1996, CRREL conducted a reconnaissance survey of the Fort Richardson cantonment area using ground-penetrating radar (GPR) to determine if it could delineate the subsurface geology (Strasser et al. 1996, Hunter et al. 1997). As part of that study, the Roosevelt Road Transmitter Site was analyzed to define the extent of buried structures. This report presents the results of these surveys and demonstrates the utility of GPR in defining buried structures.

SITE DESCRIPTION

The Roosevelt Road Transmitter Site is located on the northern side of the Elmendorf Moraine, about 1 km southeast of the Eagle River Flats and 3 km north of the main cantonment of Fort Richardson. The bunker and transmitter annex are located on a level, low-relief ridge at an elevation of 78 m above sea level. A gravel road, two large concrete foundations, four small concrete pads, and one concrete cesspool are located above ground (Fig. 2). A second cesspool is buried west of the bunker. The area was cleared of trees during site operations (Fig. 3). Following decommissioning, the site has revegetated with alder and cottonwood. Growth is especially thick along the western edge of the bunker. Two sinkholes occur there (Fig. 4); their openings are about 0.6 m square and expose the concrete walls of utilidors. Railroad ties in the utilidor ceiling had collapsed, possibly because of heavy vehicle traffic during the 1988 and 1992 remediations. The thick overgrowth limited the westward extent of our radar analyses (Fig. 5). Other sinkholes were observed along the eastern and western edges of the transmitter annex foundation, and the utilidor extending from the annex to a power hut to the north.

GEOLOGY

As mentioned above, the Roosevelt Road Transmitter Site is located on the Elmendorf Moraine, which is a major topographical feature along the northern edge of the Fort Richardson cantonment (Fig. 6). The moraine runs from the Chugach Mountains to the east, extending along the north edge of Elmendorf Air Force Base and across Knik Arm into the Susitna Lowland. This moraine was deposited between 14,000 and 13,000 ^{14}C years BP at the termination of the last major glacial readvance into the Knik Arm region (Reger et al. 1995). The multiple ridges and terraces in the moraine were formed by local fluctuations in the ice margin and by discharging ice marginal streams. The southernmost ridge represents the maximum position of ice advance. The end-moraine is composed of juxtaposed sequences of laterally discontinuous coarse gravel, fine well-sorted sand, dense silt and clay, and diamictons (mixed coarse to fine material with a fine-grained matrix).

Surficial mapping by Yehle et al. (1990) shows that the transmitter site is located on a kame-terrace. Kame-terraces form as a result of water running along the glacier margin, depositing long, narrow strips of sand and gravel between the glacier and local topographic highs (Fig. 6). Its surface is generally smooth and gently sloping. Split-spoon samples collected on-site record gravely sand and silty to sandy gravel down to a depth of about 15 m, with 10 to 30% silt and clay (Ecology and Environment 1996). Further details on subsurface materials cannot be assessed from the existing borehole logs; however, rapid vertical and lateral changes in materials are common in nearby bluff exposures (e.g., Miller and Dobrovolny 1959, Yehle et al. 1990) and are typical of ice-proximal deposits (e.g., Lawson 1979). The depth to ground water at the transmitter site is near 54 m above sea level.

METHODS

Ground-penetrating radar (GPR)

Our GPR system consists of a digital control unit (GSSI System 10+) and transducer manufactured by Geophysical Survey Systems Inc. (GSSI) of North Salem, New Hampshire (Fig. 7). The radar control unit was set to trigger pulses at a selected repetition rate of 50 kHz during the study. The received radar signals were sampled in progressive time steps and converted to audio frequency scans for display and storage at a rate of 32 scans per second. The scans were digitally stacked to improve signal quality and reduce the amount of stored information. Each recorded scan

a. 1953.

b. 1963.

Figure 3. Aerial photographs of the Roosevelt Road Transmitter Site.

Figure 4. Holes in ground surface caused by collapse of an underground utilidor.

can be displayed using an operator-selected time-range to suppress higher amplitude early returns (especially from the direct transducer coupling). This technique allows enhancement of the lower amplitude later signals that reflect at layer interfaces and material transitions at greater depths. The technique is well known and is used extensively for shallow subsurface exploration (Morey 1974, Delaney et al. 1997).

We used 100- and 400-MHz shielded dipole pairs of antennas (Fig. 8) that radiate pulses with 20- and 5-ns duration, respectively. Signals from the 400-MHz transducer were recorded at a time range of 50 ns, while deeper horizons were investigated using the 100-MHz transducer at a time range of 300 ns. Antennas were towed along the ground surface by hand or behind a 4-wheel drive vehicle (Fig. 8). The survey speed was approximately 1 m/s to maintain a close contact with the ground surface and to maximize signal transmission through the air/ground interface. This speed provided a profile data density of about 16 scans for each meter of transducer travel. Profile data were later filtered to remove noise and horizontally scaled between event markers to compensate for uneven towing speed.

GPR events in a profile consist of reflection bands from continuous horizons and discrete hyperbolic reflections that originate from individual targets and abrupt material transitions. The depth to a target is calculated from the time delay to the apex of each hyperbola when the material permit-

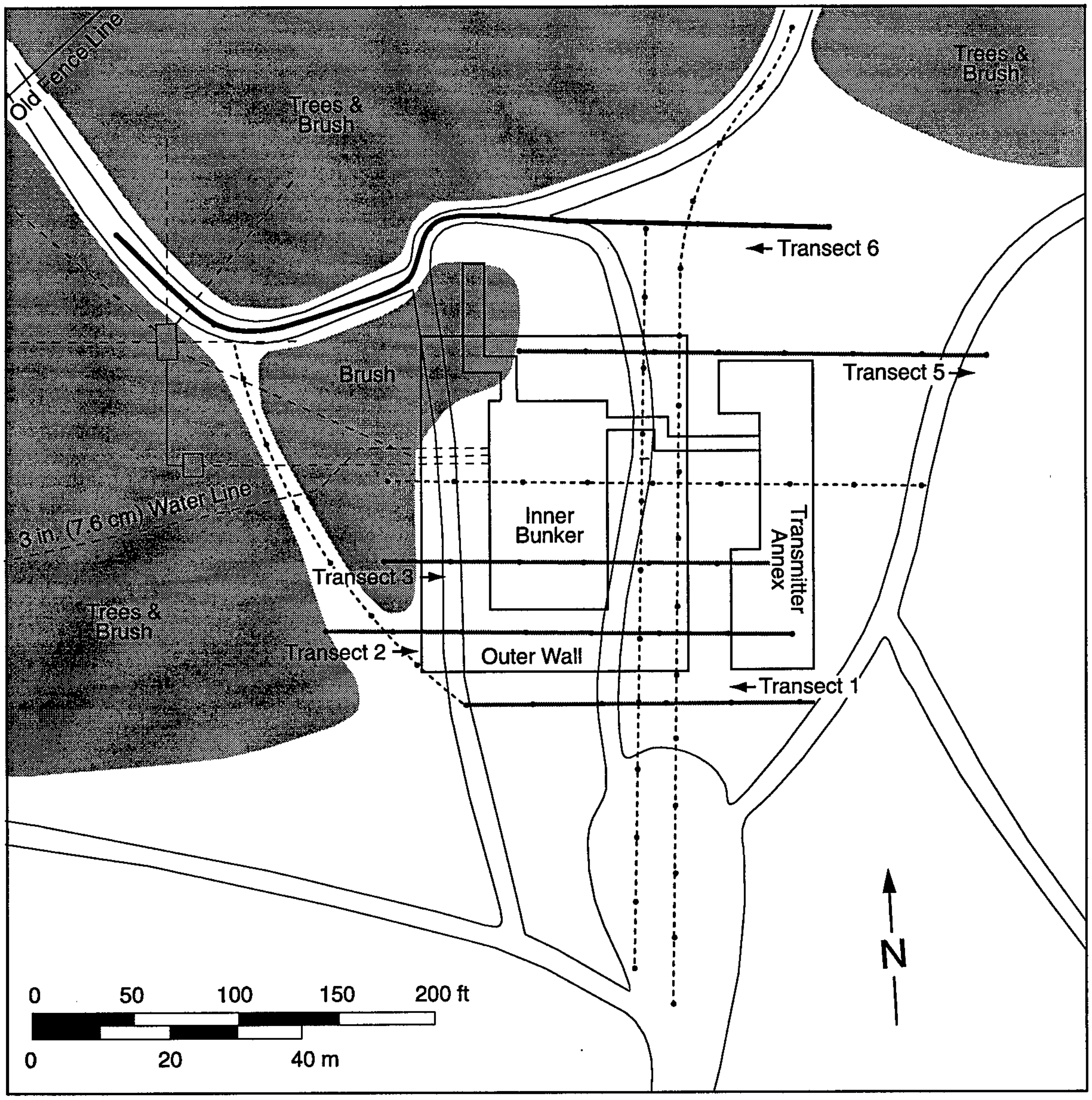


Figure 5. Layout of GPR transect lines at transmitter site. Transects discussed in this report are labeled. Arrows show direction of transect. Dashed lines show other transects run during study.

tivity, which determines the in-situ velocity, is known. Clusters of diffractions can originate from natural and man-made objects and often point to a target of interest. Strong horizontal reflections originate from the water table and various subhorizontal horizons, including continuous soil layers that contain more water than found in the surrounding materials.

All GPR profiles presented in this report show distance along the transect as the horizontal axis and the two-way travel time (t) increasing with depth down the vertical axis. Travel time may be converted to depth d according to

$$d = ct / 2\sqrt{\varepsilon}$$

where c = 30 cm/ns, the speed of radio waves in a vacuum, and ε is the relative dielectric permittivity of the soil. The factor of 2 accounts for the round trip propagation of the pulse, to and from the reflecting surface.

The dielectric permittivity of the soils at the transmitter site was determined from the time–distance slope of hyperbolic diffraction asymptotes. Permittivity was determined in June 1996 and yielded a mean soil permittivity of 11.3. The soil surface was dry and frost was absent. With

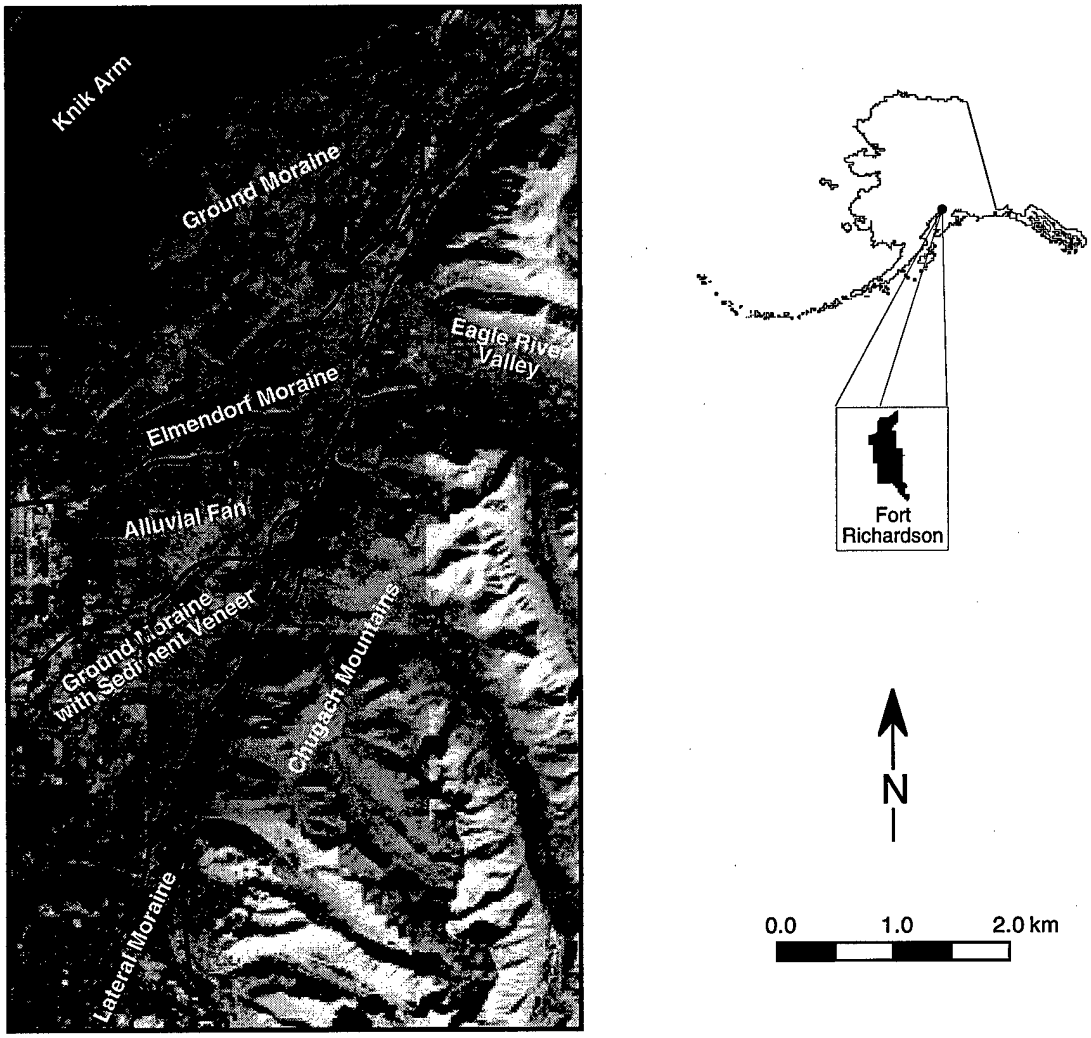


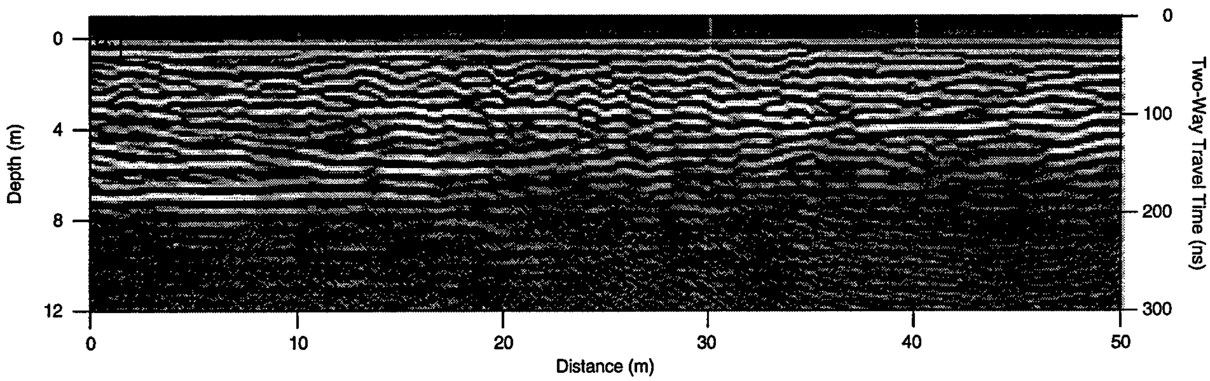
Figure 6. General geology of Fort Richardson. The study area is situated on top of the Elmendorf Moraine.

Figure 7. GSSI ground-penetrating radar system, video display, and 400-MHz transducer with cables.

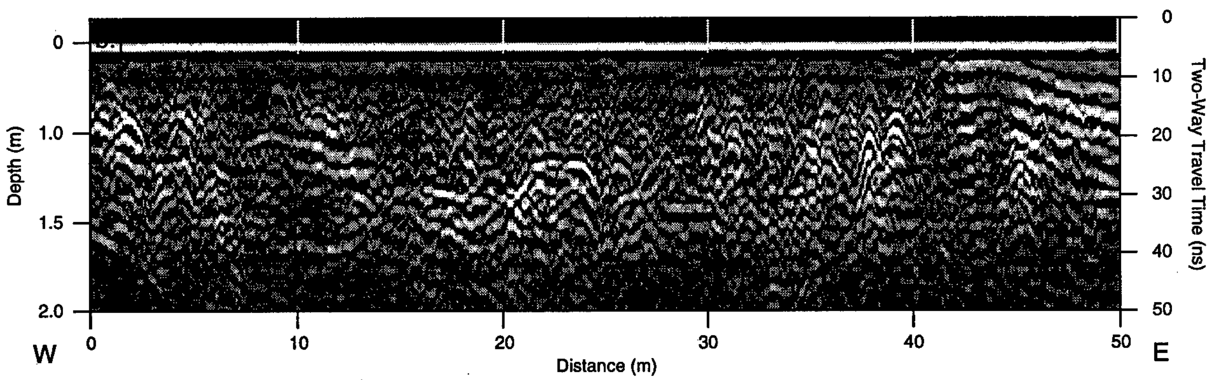
a. 100-MHz transducer.

b. 400-MHz transducer.

Figure 8. Towing of antennas behind 4-wheel drive vehicle.



a. 100-MHz transducer.



b. 400-MHz transducer.

Figure 9. Profile recorded along transect 1 away from the bunker excavation.

use of the mean ε = 11.3, the time range settings for the 100- and 400-MHz transducers provided an approximate depth range of 12.4 and 2.0 m, respectively, in these materials. The in-situ signal wavelengths are about 25 cm at 400 MHz and 1.0 m at 100 MHz. Accurate depth calibration of the radar records is difficult, however, owing to the local variability in these glacial deposits.

Measurements

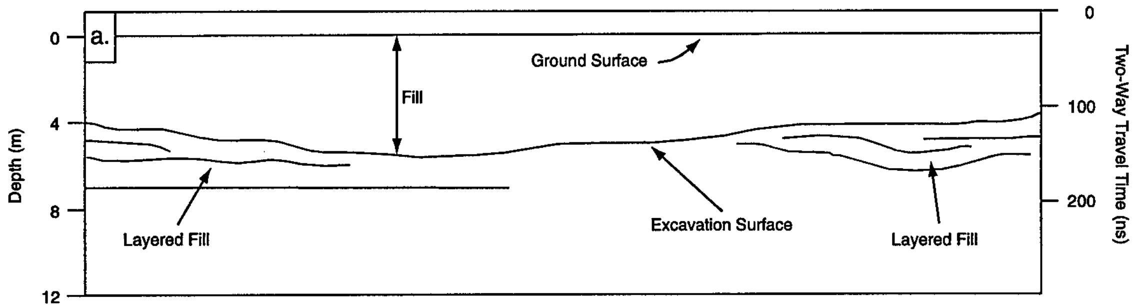
The site was surveyed during the summer of 1996, when the ground surface was dry. The control unit and data recorder were operated from the front passenger seat of a 4-wheel drive vehicle and powered directly from the vehicle's electrical system. The 100-MHz transducer was placed in a wooden sled to reduce abrasion on the bottom of the antennas and was towed approximately 10 m behind the vehicle (Fig. 8a). The smaller 400-MHz transducer was pulled by hand to maintain good contact between the antenna and the ground surface (Fig. 8b).

RESULTS

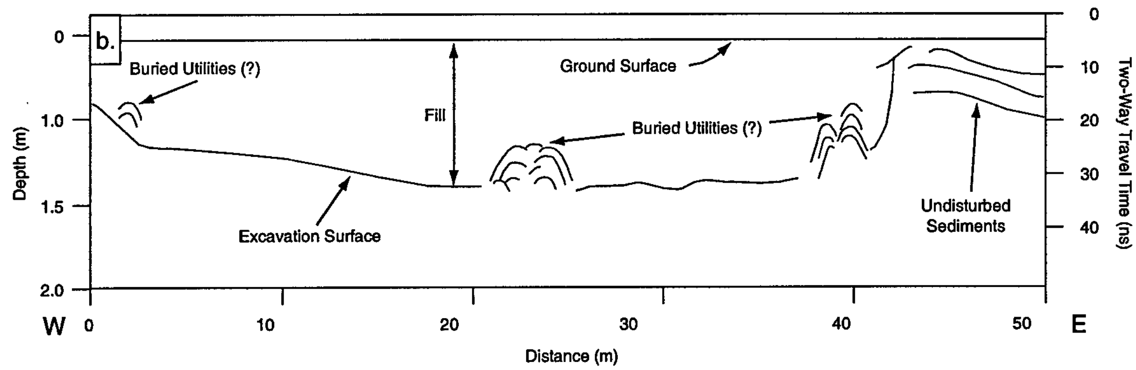
Eight transects were run near the bunker and transmitter annex, with five east–west transects selected for use in this report (1, 2, 3, 5 and 9; Fig. 5).

Transect 1

This 50-m transect was located south of the known limits of the buried bunker and utilidors (Fig. 9 and 10). The 100-MHz profile shows a subsurface horizon, which we interpret to be an excavation surface. It varies from a depth of 4 to 6 m, reaching its maximum depth about 18 m from the east side of the transect line. At distances of 0 to 10 m and 35 to 50 m along the transect, subhorizontal reflectors resembling fluvial layering are present at depths between 5 and 7 m. These deeper reflectors are truncated by a prominent horizon that appears to be the limit of an excavation (i.e., probably from the time of bunker construction; Fig. 9a and 10a). Fill above the excavation surface is characterized by closely spaced

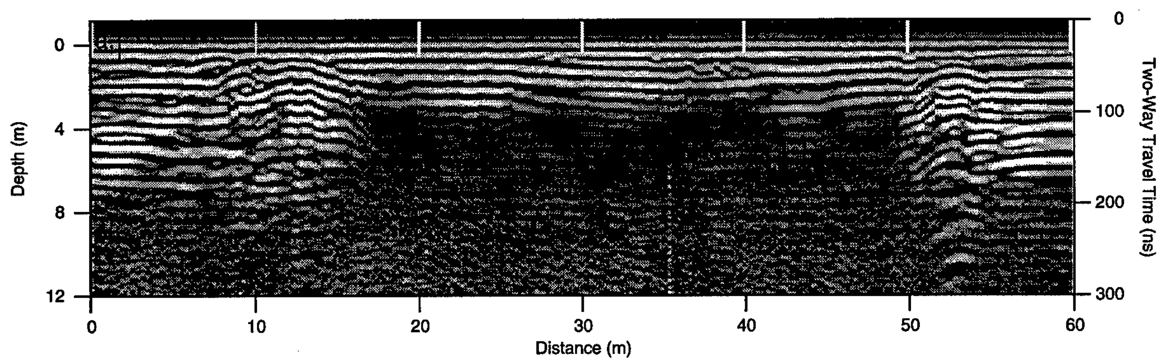


a. 100-MHz transducer.

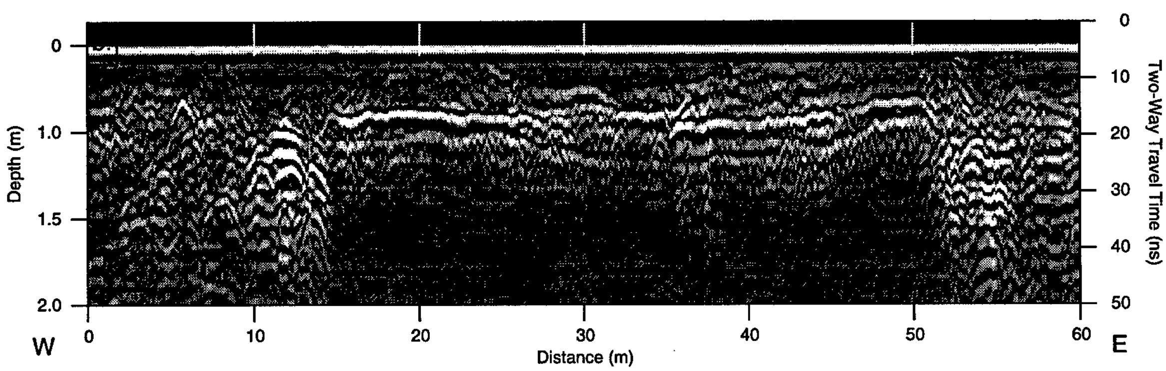


b. 400-MHz transducer.

Figure 10. Interpretive depth sections for transect 1.



a. 100-MHz transducer.



b. 400-MHz transducer.

Figure 11. Profile recorded along transect 2.

reflections that the radar wavelet could not resolve. Noise added to the signal from high-gain amplification prevents us from seeing deeper than 7 m into the ground.

The 400-MHz profile (Fig. 9b and 10b) shows details in the upper 1.5 m of the subsurface. There is a second discontinuous horizon that can be tracked from about 1 m depth at the east end of the transect to about 40 m distance, where it is truncated near the ground surface. This horizon reaches a maximum depth of about 1.3 m between 18 and 30 m along the line. Small diffractions at 2, 23, and 38 m originate about 20 cm above the discontinuous horizon. These diffractions probably originate from buried pipes or cables that were placed on a hard packed surface prior to backfilling.

Transects 2, 3, and 5

Transects 2, 3, and 5 delineate the bunker and the adjoining utilidors. Transect 2 extends 60 m from the overgrowth west of the bunker to the top of the concrete slab of the Transmitter Annex at the south end of the bunker (Fig. 5). The 100-MHz profile is distinguished by the limited penetration where the antennas were directly over the bunker, and by strong diffractions at its edges (Fig. 11a and 12a). There is a near-horizontal reflector at a depth of 5 m on both sides of the bunker (Fig. 11a). The depth of this reflector corresponds to the strong reflector in transect 1 (Fig. 9a and 10a), suggesting that it is probably the same excavation surface. The reflection bands at a depth of 50 to 70 cm above the bunker (Fig. 11b) appear to reflect its upper surface (Fig. 12b).

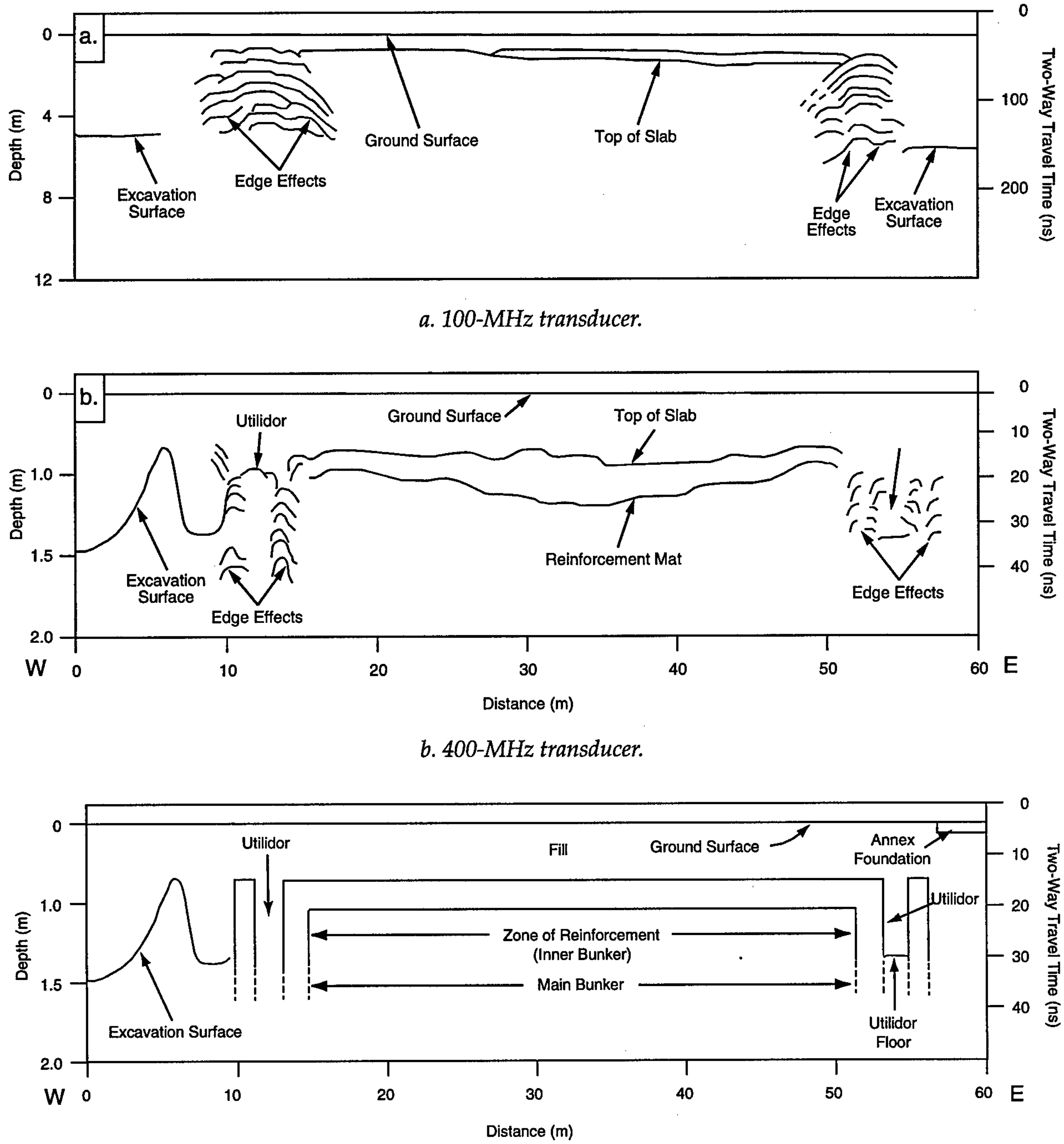
The 400-MHz profile shows distinct diffractions that originate from the utilidor structures on either side of the bunker (Fig. 12b). These diffractions appear as broad arches in the 100-MHz profile, where the wavelength is about 1.3 m long (Fig. 11a). Two distinct hyperbola sets can be distinguished in the 400-MHz data with the smaller (30-cm) wavelength (Fig. 11b). The higher resolution allows us to distinguish between the outer and inner walls of each utilidor. The top of the utilidor appears to be at about 1 m depth; a lower diffraction at 1.5 m depth and 54 m distance along the transect may locate the utilidor floor (Fig. 12b and 12c). Utilidors seen during the investigation were constructed of concrete walls, with railroad ties covered with soil for a ceiling and an earthen floor.

The distinct horizon at 70 cm depth on the 400-MHz profile (Fig. 11b) represents the top surface of the bunker. A second, slightly deeper horizon of multiple reflections represents the steel reinforcement within the bunker roof. Close inspection of this horizon reveals that it contains many closely spaced, small diffractions from individual components of the steel reinforcement mesh. A series of hyperbolas apparent between 0 and 10 m distance define a ramp-shaped mound adjacent to the western utilidor. Its closeness to the utilidor suggests that it defines the surface of an earthen berm built during site construction.

Transect 3 recorded at 400 MHz extends 50 m across the bunker, being approximately 10 m north of transect 2 (Fig. 5). The features recorded by this profile are similar to those of transect 2. The west utilidor is clearly evident between 3 and 4 m distance, as are the walls of the bunker. The small, closely spaced diffractions evident from 7 to 43 m indicate the steel reinforcement mesh (Fig. 13 and 14a). A tighter spacing of these diffractions and an apparent drop in the ceiling between the distances of 13 and 35 m suggest either a second reinforcement mesh or a double ceiling over an inner bunker (Fig. 14b). The breaks in small diffractions between 11–13 m and 35–38 m (Fig. 13) appear to be caused by edge effects and signal resonance at the outer walls of the inner bunker (Fig. 14b). A steel pipe, probably a vent pipe, was recorded at a distance mark of 23 m as a sharp resonance that extends through the entire record (Fig. 13).

Transect 5 was located at the north end of the bunker and transmitter annex, extending towards the woods to the east (Fig. 5). The 100- and 400-MHz profiles record responses from the ceiling of the outer bunker, with its reinforcement mesh, and edge effects at the outer bunker wall and utilidors (Fig. 15 and 16a,b). Several horizons are apparent on the profiles east of the bunker. The horizons adjacent to the bunker are aligned subhorizontally, with occasional hyperbolas originating at reflector horizons. These horizons on-lap a westerly dipping horizon that truncates gently dipping reflectors to the east. We interpret the horizons closest to the bunker as layered fill. The westerly dipping horizon appears to be an excavation surface that truncates natural depositional horizons to the east. The hyperbolas in the fill probably represent buried objects, such as pipes and conduits, or boulders introduced during backfill (Fig. 15b and 16b,c).

Transect 6 is located north of the bunker and extended 120 m (Fig. 5). The 100-MHz profile in Figure 17 shows a prominent reflector that extends across the transect between 4 and 7 m depth. This reflector truncates several smaller, less well-defined subhorizontal reflectors, likely to repre-



a. 100-MHz transducer.

b. 400-MHz transducer.

c. Annotated sketch of 400-MHz profile.

Figure 12. Interpretive depth sections for transect 2.

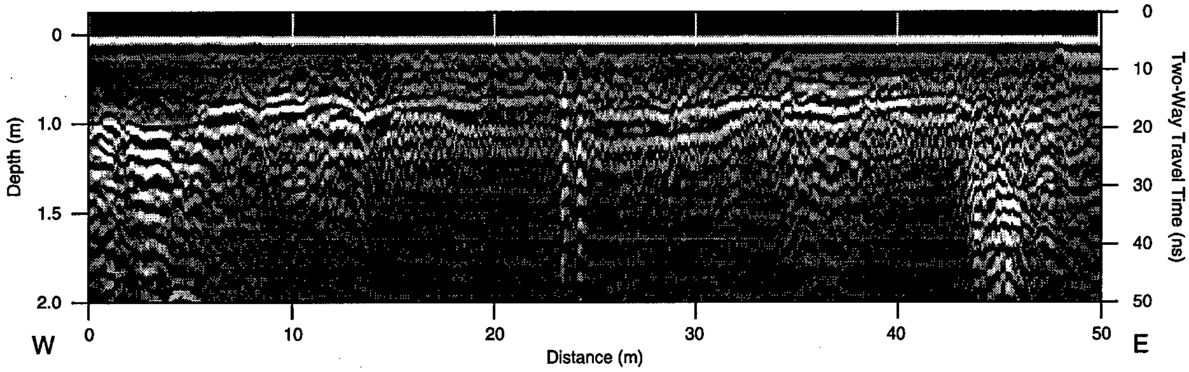
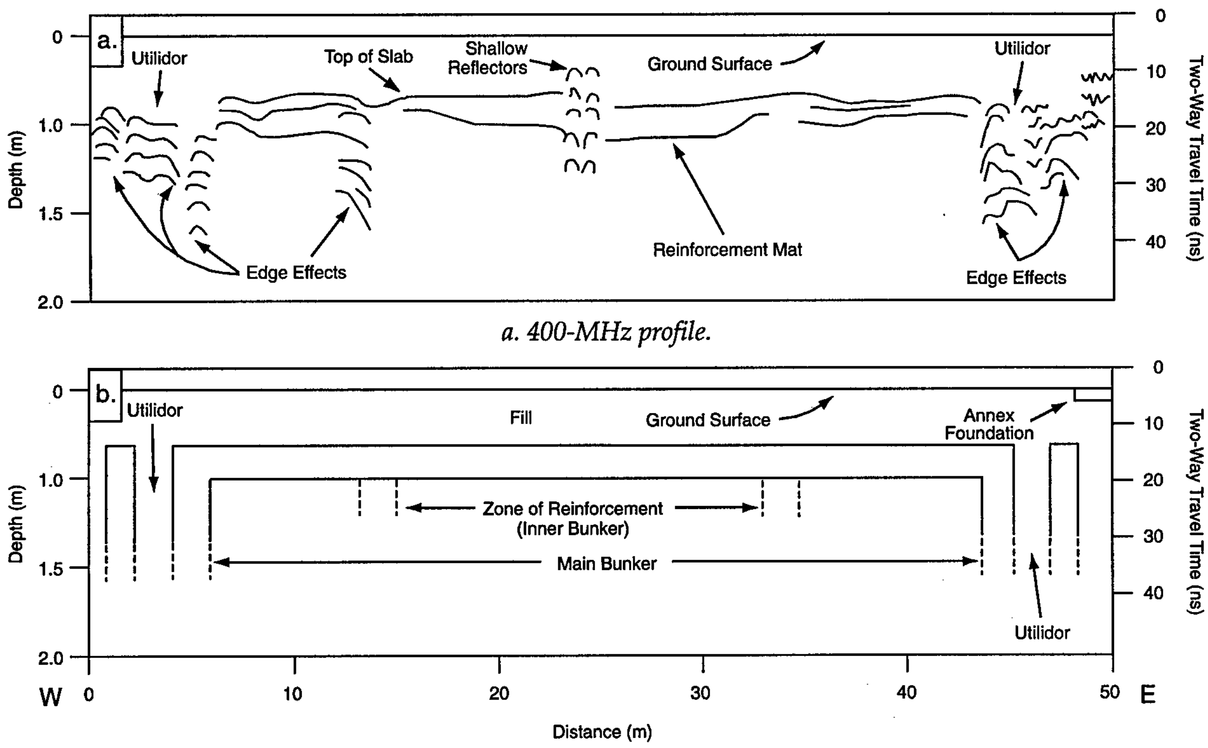


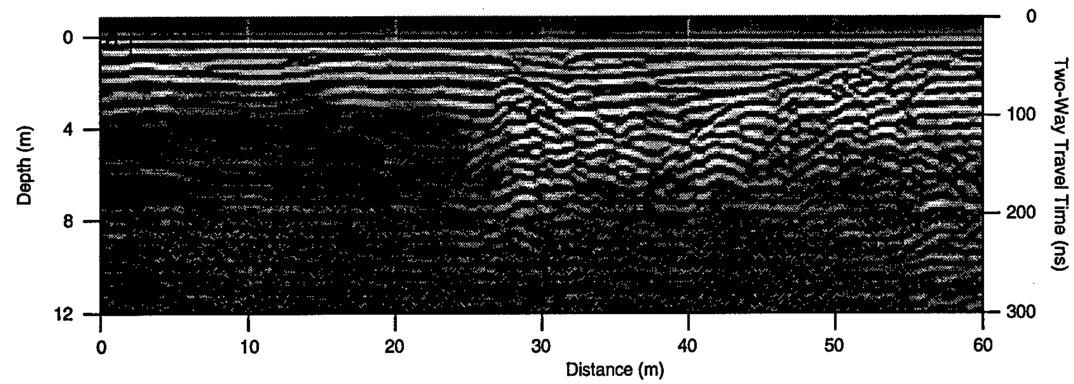
Figure 13. 400-MHz profile recorded along transect 3.



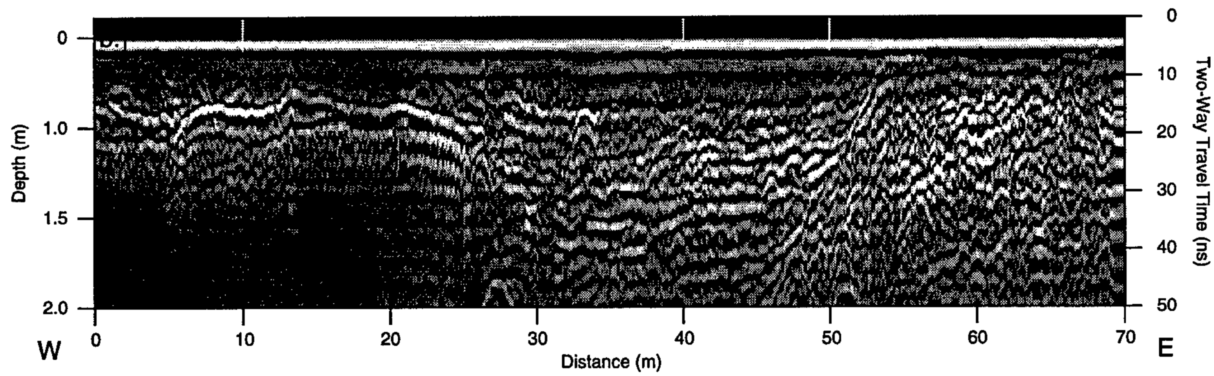
a. 400-MHz profile.

b. Annotated sketch.

Figure 14. Interpretive depth sections for transect 3.



a. 100-MHz.



b. 400-MHz.

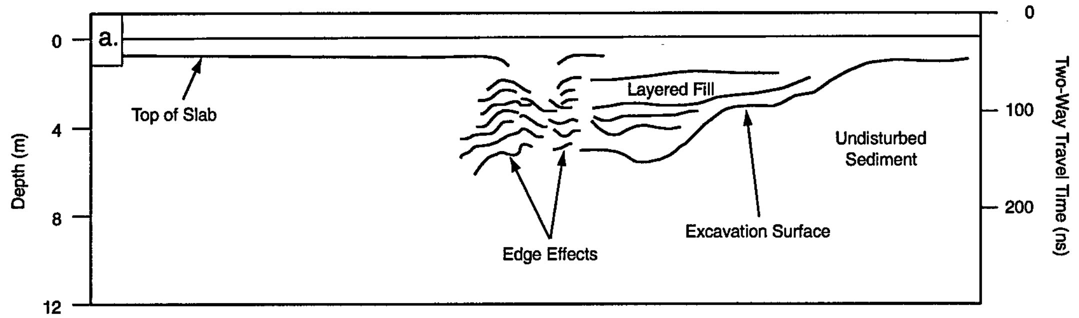
Figure 15. GPR profile from transect 5.

sent natural depositional surfaces as described on transects 2 and 5 (Fig. 12, 13, 15, and 16). We interpret this high-amplitude reflector as the lower excavation surface that became compacted during bunker construction. The hyperbolas recorded at 50 m distance likely record a utilidor that extends to the power control hut to the north (Fig. 2). Other coherent reflectors probably reflect sequential horizons produced as the site was backfilled.

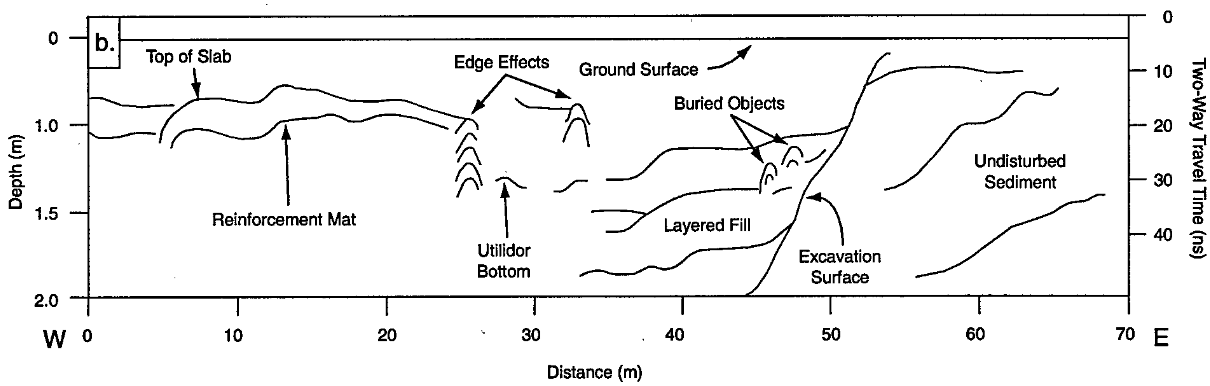
SUMMARY

Our investigations of the Roosevelt Road Transmitter Site show that GPR can delineate underground structures and associated excavation surfaces. The technology has broad application for investigating buried underground structures and anthropogenic surfaces. The analyses presented in this report demonstrate the utility of using GPR data to delineate such features. The following is a summary of our observations:

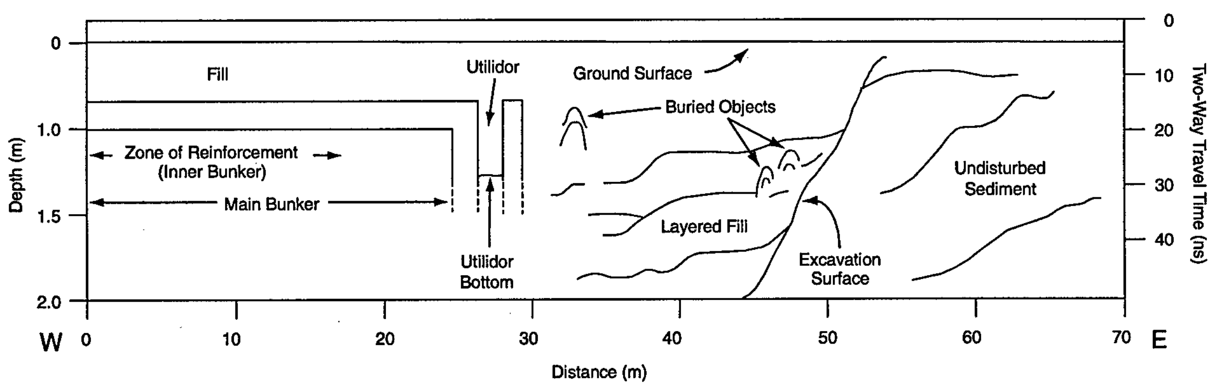
1. The 100-MHz antenna provides general details on larger subsurface structures, while the 400-MHz antenna defines features at shallower depth and in greater detail.
   - *100 MHz*: delineates limits of excavation, presence of buried structures, and large-scale stratigraphic horizons.
   - *400 MHz*: delineates shallow excavation surfaces, buried pipes, inner and outer walls of buried structures, and utilidor walls and floors.
2. Vertically stacked hyperbolas in the GPR data represent edges of the concrete walls of the bunker and utilidors.
3. Multiple, closely spaced hyperbolas in the 400-MHz data reflect the wire mesh used to reinforce the concrete in the bunker ceiling.
4. Strong subhorizontal reflections that truncate apparent depositional surfaces reveal compacted surfaces produced when the site was excavated and backfilled.



a. 100-MHz transducer.

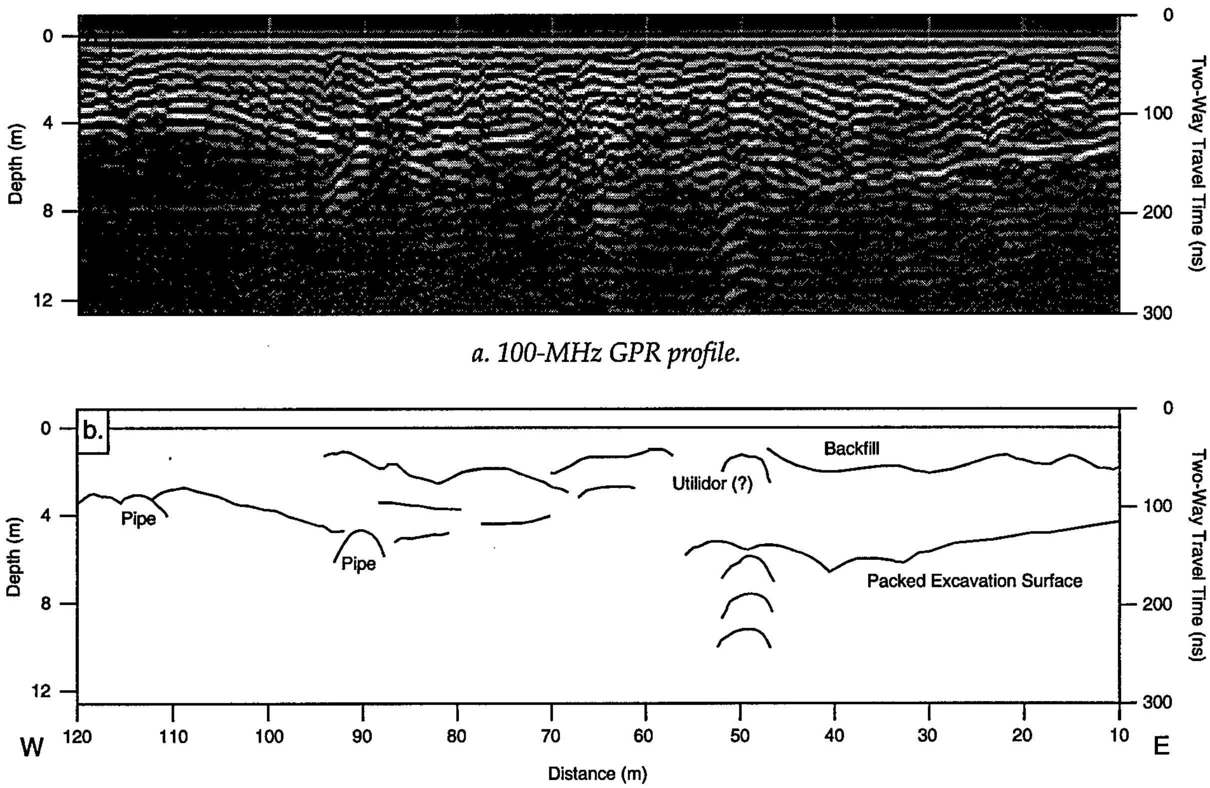


b. 400-MHz transducer.



c. Annotated sketch of 400-MHz profile.

Figure 16. Interpretive depth sections for transect 5.



b. Interpretive depth section.

Figure 17. Transect 6.

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	March 1999	

4. TITLE AND SUBTITLE
Investigation of the Roosevelt Road Transmitter Site, Fort Richardson, Alaska, Using Ground-Penetrating Radar

5. FUNDING NUMBERS

6. AUTHORS
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

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8. PERFORMING ORGANIZATION REPORT NUMBER
CRREL Report 99-4

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Directorate of Public Works
U.S. Army Alaska
Fort Richardson

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
For conversion of SI units to non-SI units of measurement, consult ASTM Standard E380-93, *Standard Practice for Use of the International System of Units*, published by the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pa. 19428-2959.

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.
Available from NTIS, Springfield, Virginia 22161

12b. DISTRIBUTION CODE

13. ABSTRACT (*Maximum 200 words*)

The Roosevelt Road Transmitter Site is the location of a decommissioned bunker on Fort Richardson, near Anchorage, Alaska. The site was used from World War II to the Korean War as part of an Alaskan communications network. The bunker and support buildings were vandalized following its decommissioning in the mid-1960s, resulting in PCB contamination of the bunker and soils around the above-ground transmitter annex. CRREL conducted a ground-penetrating radar (GPR) investigation of the site in June 1996, at the request of the Directorate of Public Works on Fort Richardson. Nine transect lines were established, each being profiled with 100- and 400-MHz antennas. Both antennas systems defined the extent of the bunker and identified the presence of buried utilidors. The 100-MHz antenna provided large-scale resolution of the bunker, limits of site excavation, and large stratigraphic horizons in the undisturbed sediments. The 400-MHz antenna provided finer resolution that allowed identification of steel reinforcement in the bunker ceiling, utilidor walls and floor, and the walls of the inner and outer bunker. High amplitude resonance and hyperbolas in the record characterize the response from the Transmitter Annex foundation, buried pipes, and utilities. The GPR survey shows its utility for detecting the extent of abandoned underground structures and identifying the extent of original ground excavations.

14. SUBJECT TERMS
Alaska — Ground-penetrating radar (GPR)
Fort Richardson — Site investigation
Geophysical mapping — Tunnel detection

15. NUMBER OF PAGES
23

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL